# Using sound to enhance taste experiences: An overview

Felipe Reinoso Carvalho[1,2], Prof. Abdellah Touhafi[1], Prof. Kris Steenhaut[1], Prof. Raymond van Ee[2,3,4], & Dr. Carlos Velasco[5]

1. Department of Electronics and Informatics (ETRO), Vrije Universiteit Brussel, Belgium
2. Department of Experimental Psychology, KU Leuven, Belgium.
3. Donders Institute, Radboud University, Nijmegen, Netherlands
4. Philips Research Labs, Eindhoven, Netherlands
5. Crossmodal Research Laboratory, Oxford University

*** Correspondence**:
Felipe Reinoso Carvalho (**f.sound@gmail.com**)
Vrije Universiteit Brussel, ETRO
Pleinlaan 2, 1050 , Brussels, Belgium

**Abstract**

We present an overview of the recent research conducted by the first author of this article, in which the influence of sound on the perception of taste/flavor in beer is evaluated. Three studies in total are presented and discussed. These studies assessed how people match different beers with music and the influence that the latter can have on the perception and enjoyment of the beers. In general, the results revealed that in certain contexts sound can modulate the perceived strength and taste attributes of the beer as well as its associated hedonic experience. We conclude by discussing the potential mechanisms behind these taste-flavor/sound interactions, and the implications of these studies in the context of multisensory food and drink experience design. We suggest that future work may also build on cognitive neuroscience. In particular, such an approach may complement our understanding of the underlying brain mechanisms of auditory/gustatory interactions.

**Keywords:** *sound, music, taste, beer, perception, multisensory experiences*

# 1. Introduction

Chefs, molecular mixologists, food designers, and artists, among other professionals working in the food industry, are increasingly looking at the latest scientific advances in multisensory flavor perception research as a source of inspiration for the design of dining experiences [26,29,30] (see [42], for a review). A number of recent studies have highlighted the idea that the sounds that derive from our interaction with the food (e.g., mastication; see [55]), can be modulated in order to enhance the sensory and hedonic aspects associated with the experience of eating and drinking, (e.g. [10,44,46]; see [41] for a review). What is more, there is also a growing consensus that the sounds and/or noise that occurs in the places where we eat and drink - such as restaurants and airplanes - can dramatically affect our perception of taste and flavor of foods and drinks ([27,28,43]; see [39,41,42] for reviews). Indeed, it has been demonstrated that several acoustic parameters that define the quality of an auditory space, such as the reverberation time of a room and the level of background noise [1,15], can affect the perception of foods; for example, in terms of how sweet or bitter they taste (e.g.,[11,48,54]; see [40], for a review of the influence of noise on the perception of food and drink).

Here, we present an overview of studies recently developed by the lead author of the present research, which assesses the influence of sound on taste[1]/flavor perception of alcoholic beverages. Three studies using beer as taste stimulus are introduced. The first assessed how the participants matched different beer flavors with frequency tones. The second studied how different customized auditory cues would modulate the perception of the beer's taste. Finally, the third study evaluated how the beer's hedonic experience can be influenced by a song that was presented as part of the multisensory beer experience. Moreover, we conclude this review by discussing the potential mechanisms behind these taste/sound interactions, and the implications of these assessments in the context of multisensory food and drink experience design. We suggest that future work may rely on cognitive neuroscience approaches in order to better understand the underlying brain mechanisms associated with the crossmodal correspondence between taste/flavor and sound.

# 2. Looking for beer-pitch matches

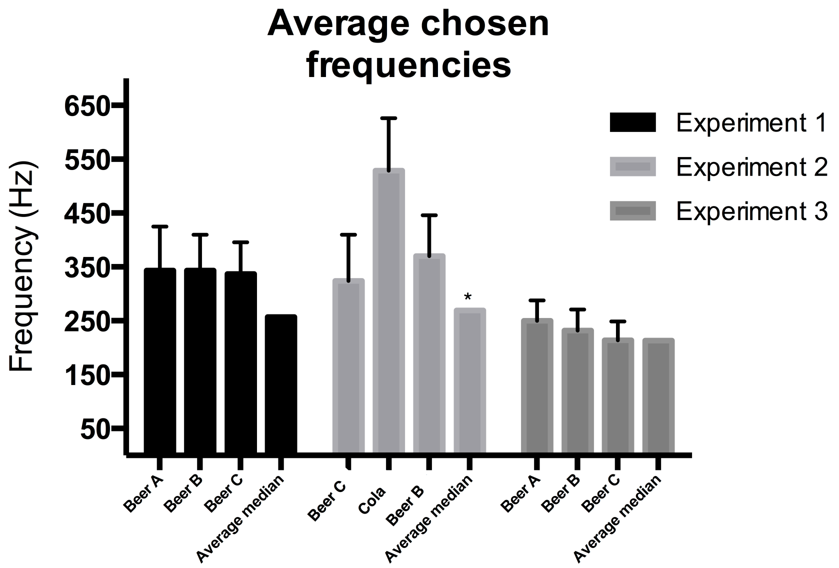
Recently, we have conducted a study designed to assess how people associate the taste of beers with auditory pitch [30]. Here, the participants were asked to choose the frequency that, in their opinion, best matched the taste of each of three Belgian bitter-dry beer types. Chemically, Jambe de Bois (Beer 1) is almost as bitter as Taras Boulba (Beer 2), but its full body and malt dominance may result in it being perceived as sweeter. Therefore, Jambe de Bois can be considered to be the sweetest of the three beers, while Zinnebir (Beer 3) comes out second due to its alcohol-plus-malt formula.

The auditory stimuli consisted of a digital version of an adjustable frequency tone generator. Using an online tone generator (Retrieved from http://plasticity.szynalski.com/tone-generator.htm, February, 2015), the participants were asked to choose the tone frequencies that in their opinion were most suitable for the taste of the beers. Figure 1 shows an image of the graphic interface.

This study included three experiments. In Experiment 1, the participant's ratings were based on a wide range of choices (50-1500Hz). Here, their results suggested that the three beers were 'tuned' around the same pitch (see Figure 1). However, in Experiment 2, the addition of a soft drink beverage alongside two of the beers, verified the fact that the participants matched the beers toward the lower end of the available range of frequencies, and the soft drink toward a higher tone (see Figure 1). Note that, in Experiments 1 and 2, the majority of the results fell within a much narrower range than what was available to choose from. Consequently, in Experiment 3, the range of frequencies was reduced to 50-500Hz. Under the new frequency range, the obtained means - and medians - were matched to tones in the same frequency range, as those medians that derived from Experiments 1 and 2 (see Figure 1).

[1] By taste we refer to the basic components that are mostly captured by the tongue (sweetness, saltiness, bitterness, sourness and umami). Flavor, on the other hand, is a more complex experience that also involves, at least, retro nasal olfaction.

**Figure 1.** Average chosen frequencies in experiments 1, 2, and 3. Here, we can visually appreciate that the average medians in the three experiments are in the same range with the means obtained in Experiment 3 (error bars show the upper limit of the confidence interval of the means). Note that the average median in Experiment 2 is based on the median values of the two beers used in such experiment, not including the correspondent median cola value (marked with an asterisk '*').




These results demonstrate that participants reliably match beverages, with very different taste profiles, to different frequencies, and, as such, consistently matched bitter beers to a low - and narrow - band of sound frequencies. Therefore, we further confirmed the hypothesis that people tend to associate bitter flavors with low audible frequencies, and sweet flavors with high audible frequency ranges [44].

One limitation of the current study, given the multisensory nature of flavor perception, is that, it is not entirely clear on what basis did the participants make their beer-pitch matching (e.g., on the basis of the beer's aroma, mouthfeel, taste, etc…). Future research may explore the different components of the beer's flavor. For example, are such beer-pitch associations made solely on the basis of the aroma of the beers? It is important to consider here the potential bias effects that may derived from the beer's extrinsic properties, such as their different colors (that should not be accessible to the participants) and/or the homogeneity in the amount of foam present in all samples. Finally, further studies may attempt to understand the perceptual effects of matching/non-matching tones on the multisensory drinking experience. Perhaps, as we will see later, it may be possible to modulate the beer's taste by manipulating the auditory cues that accompany the taste experience.

## 3. Modulating beer taste and strength by means of customized songs

Another study involving beer conducted by Reinoso Carvalho et al. [31] analyzed the effect of three songs on people's perception of the taste of the beer. The participants tasted a beer twice, and rated the sensory and hedonic aspects of the beer (likeness, perceived sweetness, bitterness, sourness and alcohol strength), each time while listening to a different song[2]. Here, the objective was to determine whether songs that have previously been shown to correspond to the different basic tastes would significantly modulate the perceived taste, and alcohol content of the beers (see [51], for the procedure on how the songs were classified - note that this is the first time this type of studies is made with beers as taste stimuli). The three beers used in the present study were Belgian bitter-dry types (the same three beers presented in Section 2).

For this study, three experiments were developed. The independent variable for each experiment was therefore sound condition, and the dependent variables were the ratings

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[2] Link to the songs http://sonicseasoningbeer.tumblr.com/ (retrieved on March, 2016).

that the participants made for each beer. In Experiment 1, the participants tasted Taras Boulba while listening to the sweet and bitter songs. In Experiment 2, they tasted the Jambe de Bois beer while listening to the sweet and sour songs. In Experiment 3, the participants tasted Zinnebir while listening to the sour and bitter songs. Each beer was assigned to the experiment with the songs that expressed the most prominent taste in the beer. Therefore, Taras Boulba, which was ranked as the most bitter, was used in Experiment 1, where the bitter and sweet songs were played. Jambe de Bois, which was ranked as the sweetest, was used in Experiment 2, where the sweet and sour songs were played. Zinnebir, which was ranked in-between the two other ones, in both scales, was used in Experiment 3, where the bitter and sour songs were played. The songs were presented in a counterbalanced order.

The songs were found to influence the participants' rating of the taste and strength of the beer (see Figure 2).

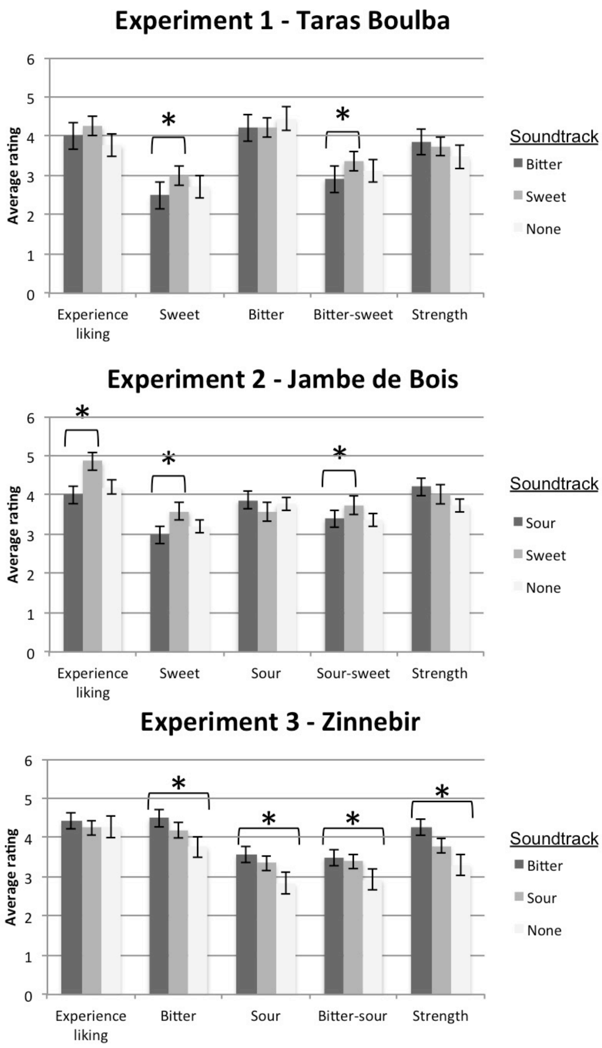



**Figure 2.** Comparison of beer ratings (means and standard error bars) made while listening to songs versus silence. All ratings were made on a 7-point scale, with "1"=not at all and "7"=very much. The asterisk '*'indicates a significant difference ($p<.05$). Source of Figure [26]

In Experiment 1, the participants rated the beer as significantly sweeter when listening to the sweet song than when listening to the bitter song. In Experiment 2, the participants rated the beer as tasting significantly sweeter while listening to the sweet song than while listening to the sour song. No significant differences were found when comparing taste ratings in Experiment 3. However, only in Experiment 3, the participants rated the difference in alcohol strength as significant (the beer was perceived as more alcoholic while listening to the bitter song than when listening to the sour song). The results also revealed that most participants liked the sweet song when compared to the bitter and sour ones. In general, they did not like the bitter song and really did not like the sour song, when compared to the sweet one. Furthermore, a control experiment (Experiment 3) without sonic stimuli confirmed that these results could not simply be explained in terms of order (or adaptation) effects. These results may be explained in terms of the notion of sensation transference [5]. That is, while listening to the pleasant sweet song, the participant transfers his/her experience/feelings about the music to the beer that they happen to be tasting. This, in turn, results in higher pleasantness and also higher sweetness ratings (when compared to, in this case, the relatively less pleasant sour and bitter songs), given the hedonic characteristics of such a taste.

Finally, here, for the first time, we demonstrate that it is possible to systematic modulate the perceived taste and strength of beers, by means of matching or mismatching sonic cues. These results open further possibilities when it comes to analyzing how the emotional aspects involved in sound-beer experiences can affect such crossmodal correspondences.

## 4. Analyzing the effect of customized background music in multisensory beer-tasting experiences

This study [32] focused on the potential influence of background music on the hedonic and perceptual beer-tasting experience. Here, different groups of customers tasted a beer under three different conditions. The control group was presented with an unlabeled beer, the second group with a labeled beer, and the third group with a labeled beer together with a customized sonic cue (a short clip from an existing song).

The beer used in this experiment, namely 'Salvation', was a one-time-batch limited edition, and a co-creation between The Brussels Beer Project (TBP), and an UK music band called 'The Editors[3]'. The complete description of the creative process involving the development - and characterization - of the experimental taste and sonic stimuli can be accessed in the following link: http://tbpeditors-experience.tumblr.com/ (Retrieved on March 2016). A fragment of the song 'Oceans of Light', from the previously-mentioned band was chosen as the sonic stimulus for this experiment. The fragment contained around one minute of the original song (from minute 2:25 to minute 3:25, approximately[4]. By relating the musical and psychoacoustic analysis with the summary of the cross-modal correspondence between basic tastes and sonic elements presented by [18], we predicted that the song may modulate the perceived sourness of the beer[5].

The full study was divided into three main steps. In the first step, the participants inserted their personal information, read, and then accept the terms of the informed consent. The second and third steps were different for each of the three experimental conditions. In Condition A, the participants evaluated the beer presentation without any label in the bottle, tasted the beer afterwards and answered some questions regarding their beer experience. In this condition, the participants did not have any information regarding the origin of the beer. In Condition B, the participants evaluated the beer presented with its label on the bottle, tasted the beer afterwards, and answered some questions regarding their beer-tasting experience. Here, they were informed that the beer that they were tasting was the product of a collaboration between TBP and The Editors (band). Finally, in Condition C, the participants evaluated the beer's presentation with its corresponding label, tasted the beer while listening to the chosen song, and answered some questions regarding their beer-tasting experience. The participants in conditions B and C were told that the beer being tasted was the product of a collaboration between TBP and The Editors (band), and that the song that they listened to was the source of inspiration for the formulation of this beer. The questionnaires of steps two and three were fully randomized.

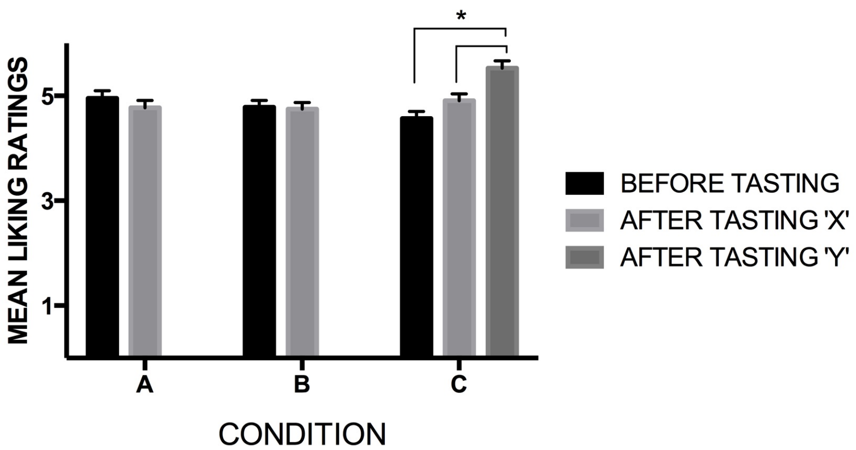
[3] See http://www.editorsofficial.com/ (retrieved November 2015).

[4] Link to the song - https://play.spotify.com/track/4yVv19QPf9WmaAmYWOrdfr?play=true&utm_source=open.spotify.com&utm_medium=open (retrieved January 2016)

[5] For example, in [17]'s Table 1 - which summarizes the results of a number of studies carried out by different research groups - high spectral balance, staccato articulation, syncopated rhythm, high pitch, among others, are musical/psychoacoustic elements that correspond to sourness. Furthermore, due to the predominant piano in the second verse, the song might also be expected to have an effect on the perceived levels of sweetness.

The results suggested that music may as well be effectively used to add value to multisensory tasting experiences when there is a previous connection between the participants and the music (see Figure 3).
Concerning taste ratings, the song seemed to have a modulatory effect on the perceived sourness of the beer. However, the ratings of Conditions A and C are mostly indistinguishable, and significantly higher when compared to the ratings in Condition B. Similarly, the participants reported that the beer tasted significantly stronger when it was presented without labeling (Condition A), and in Condition C, when the beer's presentation was accompanied by the song, than in Condition B. In the two cases mentioned above, it would seem that drawing attention to the visual aspects of the label, in Condition B, had a negative effect. In particular, we suggest that in Condition B, the semantic contents of the label may have counterbalanced the perceived sourness, and, in Condition C, the song may have enhanced it. Another potential relevant factor present in the label was the visual impact of the diagonal white line. Such line goes from top left down to bottom right. Another study recently reported [**55**] that consumers potentially have a preference for an oblique line ascending to the right, when evaluating plating arrangements. Something similar is likely to be found with product packaging. In summary, the white line was in the opposite direction as the probable preferred choice of the customers that experienced the label.

**Figure 3.** Mean ratings of the evaluation of the subjective aspects of the tasting experience, with 'X' being the ratings of how much they liked the beer (X), and 'Y' the likeness ratings of the sound-tasting experience (Y) [ratings based on 7-point scales, being 1 'not at all', and 7 'Very much']. Visualizing these evaluations, it seems that the participants valued the customized soundscape component of the multisensory beer-tasting experience. The error bars represent the standard error (SE) of the means here and in all the other graphs of the present study. Significant differences between the specific interactions are indicated with an asterisk '*' (p-value for the comparison before-tasting and after-tasting ratings 'Y' ($p$ = .001); p-value for the comparison after-tasting ratings 'X' and 'Y' ($p$ < .001) – this figure was taken from open access publication, published in Frontiers in Psychology [27].




One potential limitation of the present study is that it was implemented in a brewery with its own customers and, hence, all of the participants were constantly influenced by the brand, which potentially provided brand-specific cues that may also have contributed to the findings. Future research could develop a similar experience in a more typical drinking environment, such as a common bar, including neutral glassware and a more balanced audience[6]. Here, it was also not possible to discriminate the influence of the given messages in Conditions B and C (cf. [28]). A future implementation may consider delivering such message only to the participants being stimulated by a song (i.e., in this experiment, only to the participants in Condition C).

[6] 83% of the participants reported knowing TBP (N=191). When asked how often the participants consumed products from TBP - on a 7 point scale, with 1 corresponding to 'never' and 7 to 'very often' - the mean of their answers was 3.30 (SD 1.80). Note that, since the vast majority of the participants reported knowing TBP, in this study it was not possible to include in our data analysis control for familiarity of the beer's brand.

## 5. Discussion and future work

### 5.1 General Discussion

With the studies reviewed in this article, we have showed that soundscapes/music can influence taste (and potentially flavor) attributes of drinks. With that in mind, we suggest that sound can be used to "liven up" the overall eating and drinking experience. For example, a bitter chocolate (or a bitter beer) accompanied by high-pitched sounds may be perceived as less bitter, making its consumption more pleasant - and potentially with less added sugar - for those who prefer sweeter tastes.

So, why auditory cues would influence taste perception? As suggested by [47], when thinking about the modulation of taste perception via sonic cues, it is perhaps difficult to point to a single mechanism that explains the range of effects reported in the literature. Relevant to the studies presented here, [47] suggests that crossmodal correspondences, emotion, and/or sensation transfer may potentially explain the different effects reported in the literature. For instance, crossmodal correspondences may influence taste perception via psychoacoustic features that match or mismatch attributes or features such as sweetness, bitterness, and/or sourness; such features may draw people's attention towards specific taste attributes (see section 2; see [18] for an overview). Whether or not features match another feature may depend on multiple mechanisms as suggested by [38]. Note, however, that in more everyday life people are rarely exposed to a single psychoacoustic feature while eating. Moreover, whilst it may be possible that a song and/or soundscape have a dominant or a series of dominant psychoacoustic features, music in itself is a more complex construction, and is usually under condition of our own personal preferences. For that reason, the emotional connotation of specific auditory stimuli (either a feature or a more complex sonic stimulus) could transfer to the experience of the food/beverage and thus influence their specific sensory and hedonic characteristics. A pleasant song may therefore lead to higher pleasantness and eventually sweetness ratings (as sweetness tends to be pleasant and thus it matches the pleasantness of the song) - when compared to a relatively less pleasant song (see section 5; see [5], for a review on sensation transference). Importantly, it has also been shown that a person's mood can influence their ability to detect olfactory (e.g. [25]) and gustatory stimuli [13,14]. In that sense, emotions induced by music can have an attentional effect on the way people perceive taste. Recently, [17] showed that sweetness can be perceived more dominant when the music that is played is liked by the participants, when tasting a chocolate gelati (Italian ice cream). On the other hand, bitterness seems to be enhanced when people dislike the music. This seems to be consistent with the idea that certain crossmodal correspondences may be explained by a common affective connotation of the component unisensory cues that people match [47]. Importantly, more than one study have concluded that liking or disliking the music that people hear while tasting can have a significant effect in the levels of enjoyment of food/beverages [12,16].

As a next step for future research, it will be critical to test the different mechanisms behind sound-taste interactions (i.e. crossmodal correspondences, sensation transference, attentional redirection, among others). Important to say here that the assessment on how sounds – that not necessarily derive from our interaction with food (e.g., mastication, such as in [20]) - influence taste/flavor perception is relatively new, with most of its conclusive results coming from the last ten years. Therefore, we could presume that the existent methods that are here being applied – and revised – are not so well-established yet, when referring to this specific sensorial combination. As such, we believe that future behavioral studies may well be combined with neuroscientific methods. Such combination may help to provide a better understanding on the brain mechanisms that underlie sound/taste correspondences. Take, for instance, the 'Sensation Transference' account described by [5], which we suggest as a possible explanation for the modified hedonic value of food/drink experiences that involve sonic cues [31,32]. For example, in [31], it seems that the participant transfers his/her feelings about the music to the beer that they happen to be tasting. Potentially, one possible approach for understanding the relationship between sound and taste, at a neurological level, would be to focus on the way in which the affective value of gustatory and auditory information is encoded by the brain [34].

In the paragraphs below, we will present a short overview about multisensory perception from the perspective of cognitive neuroscience. Afterwards, we will introduce a few studies that have approached how the brain processes music and taste/flavor, separately, hypothesizing on the potential associations between music-food at the brain (mostly related to pleasantness). Finally, we will introduce a few approaches for potential future work, following the quite recent – but already existent – blend of psychophysics and neuroscience towards chemosensory/auditory interactions.

### 5.2 Sound and taste from a multisensory integration perspective?

Most studies on multisensory integration have been focusing on vision and its interaction with audition. So, one question that still remains open is, when thinking about the interaction of sound and taste/flavors in the brain, should we focus on multisensory integration? Or, perhaps, on the way in which sonic cues may prime specific mechanisms that end up having a significant influence on taste/flavor perception, without the necessary need for integration?

Multisensory integration – i.e. the interaction between sound and taste – seem to be the product of supra-additive neural responses, at least when it comes to the temporal and spatial characteristics of multisensory cues [37]. This means that, for instance, the response that a neuron produces to sight and sound that co-occur at more or less the same time and from the same spatial location, may be greater than the summed responses to either the sight or sound alone (e.g. [52]). [7] also argues that a multisensory interaction may be a dialogue between sensory modalities rather than the convergence of all sensory information onto a supra-modal area. For instance, [7] suggests that the Bayesian framework may provide an efficient solution for dealing with the combination of sensory cues that are not equally reliable [7], and this may fit into a sound-taste/flavor model. [49] also suggests that the identification and quantification of the effects of multisensory response may demand a comparison between the multisensory versus the single modality response, with the latter evoked by a single specific stimulus. In other words, in some cases, it is also practical to compare the multisensory response to, for example, models in which the unisensory responses are summed, or comparing models that are potentially ideal representations of a predicted response, obtained by the best combination of the unisensory inputs.

However, space and time are not be the only factors potentially underlying multisensory integration. Research also suggests that semantic congruency and crossmodal correspondences may also facilitate multisensory integration [38] In particular, semantic congruency can be understood by those situations where, for example, auditory and vision cues are integrated because the different sensory cues belong to the same identity or meaning, as it happens with the picture of a dog and the barking sound of a dog, where both belong to the object 'dog' [4,9,38]. Crossmodal correspondences, on the other hand, can be thought of as the associations that seem to exist between basic stimulus attributes across different sensory modalities (i.e. correlations between different basic taste attributes within different frequency ranges, and so on) [23,38].

Now, when thinking about how taste and sound interact, we know that what we hear can help us to identify the gustatory properties of what we eat. For instance, research has shown that modifying food-related auditory cues, regardless the fact that those sounds may come from the food itself or from a person's interaction with it (think of carbonated beverages, or a bite into an apple), can have an impact on the perception of both food and drink ([48]; see [41] for an overview; see [3] for more general principles). Still, in order to improve our understanding on taste/flavour-audition interactions (especially referring to those sounds that not necessarily derive from our interaction with food, but that nevertheless can still have a significant influence on the final tasting experience), it seems to be critical that future studies focus on the spationtemporal and semantic aspects of those senses, as well as the crossmodal correspondences that have been shown to exist between tastes/flavours and sonic features [36,45].

### 5.3 Using neuroscience to assess the mechanisms behind sound-taste correspondences

If one intend to build up a case for assessing the interaction of sound and taste/flavor at a cognitive level, which factors should one consider to start with? Listening to music seems to be mostly about pleasure and, still, we give as much inherent value to it than to eating and/or drinking. On the other hand, feeding ourselves comes as a need, regardless the fact that we will always be able to eat food (and drink beverages) that we find 'pleasant enough'. However, it seems that a potential successful baseline to build a solid cognitive relation between music and taste/flavor may be the fact that both stimulus, under the correct circumstances, can provide us with pleasure (note that this has been suggested as a possible mechanism for crossmodal correspondences; see [21,38,50]). As such, we could consider, as starting point to work, for example, with the hypothesis that the valence associated with a song or sonic parameter would have perceptual and/or hedonic effect on one's eating/drinking experience. Assuming that we are pursuing this path, which involves emotions, one way may be to refer to the affective account of crossmodal associations that are based on a common affective connotation. Here, we refer to the extent to which two features may be associated as a function of their common hedonic value ([6,8,22,46,21,50].

In any case, it would seem that when assessing how the brain perceives music, emotions come as a logical path to explore. Researchers have recently shown [53] that the interconnections of the key circuit for internally-focused thoughts, known as the default mode network, were more active when people listened to their preferred music. They also showed that listening to a favorite song alters the connectivity between auditory brain areas and the hippocampus, a region responsible for memory and social emotion consolidation. As suggested by [53], such results were unexpectedly consistent, given the fact that musical preferences are uniquely individualized phenomena and that music can vary in acoustic complexity and message. Furthermore, their assessment went further to previous ones, that focused simply on how different characteristics of music (i.e., classical versus country) affected the brain. Here, they considered that most people when listening to their preferred music (regardless of the type), often report experiencing personal thoughts and memories.

Other researchers have also used brain imaging to show, among other things, that the music that people described as highly emotional engaged the reward system in their brains - activating subcortical nuclei known to be important in reward, motivation, and emotion [2]. They also found that listening to what might be called "peak emotional moments" in music causes the release of dopamine, that is an essential signaling molecule in the brain [33]. That is, when we listen to music that we find pleasant, dopamine is released in the striatum. Dopamine is known to respond to the naturally rewarding stimuli – just like when we consume food.

As hypothesized above, it seems that emotional assessments could provide us with interesting outcomes. For example, what would happen if we eat chocolate while listening to our favorite songs, versus eating the same chocolate while listening to background noise at unpleasant/uncomfortable levels? Even before eating, when simply thinking about eating chocolate while being hungry, our bodies start to create expectations about the future eating experience[7]. Therefore, what would happen with our expectations (and their corresponding neural processes) while listening to different sonic cues, considering that they might be emotionally related to the subject being sampled? Or could, perhaps, our favorite songs help us reducing the negative emotional impact that eating low-sugared chocolate may bring into our daily lives? With a better understanding of the cognitive mechanisms behind such multisensory interaction, Music could not only be used to modulate the multisensory tasting experience, but it could, perhaps, also be used to modulate its previous expectations, in order to potentially prime the mind before eating/drinking.

Summarizing, as a future objective in this research path, we propose to continue extending the recent research that have started to raise these same questions, by blending psychophysics and neuroscience to chemosensory/auditory interactions (see [35] for a review on the influence of auditory cues on chemosensory perception). Since behavioral tests have been proven to be effective methods for assessing, for instance, emotional response (or its correspondent valence), it seems that a combination with

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[7] A few quick notes on how chocolate works in the brain were reviewed from both of the following links. http://science.howstuffworks.com/life/inside-the-mind/emotions/chocolate-high2.htm and http://healthyeating.sfgate.com/chocolate-dopamine-3660.html (retrieved on February, 2016); see [24] for a review on mood state effects of chocolate.

cognitive neuroscientific approaches would help in a better understanding of the physiological state (arousal) while reacting to multisensory stimuli[8]. However, at some point, it would be prudent to consider that the relation between valence and arousal seem to vary with personality and culture, especially when dealing with subjective experiences [19].

Finally, from a design perspective, it is possible to customize the external sonic cues that may be involved in the eating/drinking process, with specific perceptual objectives, and without the need of altering a food/beverage product's physical appearance.

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[8] Important to note here that arousal and valence are the most common ways to characterize changes in emotions. In other words, the relation between high/low arousal and positive/negative valence are used to define an emotional state.

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